XL403D
User's Manual

REV.	Date	Description	Updated Pages
1.00	November 2012	Initial Release	
1.01	February 2013	Add calculation to section covering the INP:FILT:FREQ command to take into account the interaction between the 5-pole Butterworth filter and the built-in low-pass filter in the sensor.	
1.02	June 2013	Removed statement to support RS485 BAUD rates up to 1Mb/s. Currently, RS485 supports the same BAUD rates as RS232.	4
1.03	July 2013	Added documentation to the SYST:ERR? Command to show all the output bytes and document their meanings.	26
1.04	July 11, 2013	Changed text regarding pins 5 and 6 and the RS-485 interface to match the specifications in the data sheet.	10
1.05	August 6, 2013	Changed diagram regarding pins 5 and 6 and the RS-485 interface to match the specifications in the data sheet.	34

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1.0 Description

1.1 Product Overview

The XL403D is a rugged digital accelerometer that is extremely versatile, intelligent and works independently. For ease-of-use, the XL403D is configured and programmed through an ASCII-based command set that resembles the Standard Commands for Programmable Instruments (SCPI) protocol. The XL403D does not conform to the standard, so the commands are only SCPI-like. The command set allows the sensor to be integrated with external data acquisition and processing systems.

1.1.1 General Features:

- Offset temperature compensation from -40°C to +85°C.
- ASCII-based SCPI-like command set.
- Programmable 5-pole Butterworth filter.
- Firmware upgradability after unit manufacture.
- Continuous scanning of up to 4 channels (3 axes, 1 temperature).
- Each channel is fixed as a direct sensor input.
- Displays measurements over the serial interface.
- User-configurable scan rates based on time intervals.
- Triggered scans via a TTL-level signal on the ST/AUX line.
- Multiple-sensor synchronization through the ST/AUX line.
- Able to analyze the measurements that it takes by using functions.
- Readings are returned in engineering units (g's, °C) or raw ADC counts.
- Unit can accommodate RS232 baud rates from 300 to 115,200 through the 35250A PC interface.
- Unit supports RS485 natively through an RS485-to-USB interface (purchased separately).
- Internally-stored calibration data for each channel, including temperature compensation coefficients.

1.2 Product Specifications

The datasheet specifications listed below are valid within one year of calibration.

This data is subject to change without notice. For the most recent product specification, go to http://www.specsensors.com/manuals.asp for an updated datasheet.

1.2.1 XL403D Datasheet

T_a = Tmin to Tmax; $8.5 \leq V_S \leq 36$ V; Acceleration = 0 g unless otherwise noted

Range Measurement Full Scale	±1	±15	g	Factory-configured n each axis. Must specify via Option Rnnn
Sensitivity At 25°C, Option R005 Drift T_{min} to T_{max}	400† ±0.65	±3	mV/g %	Precise values on Cal certificate Percent of sensitivity at 25°C
Zero g Bias Level At 25°C Drift T_{min} to T_{max}	2.5 20		V mg	Precise values on Cal certificate At 1.25°C/min. temperature rate of change
Alignment Deviation from Ideal Axes	±1.0	±3.0	degrees	Precise values on Cal certificate Can be compensated if required
Transverse Sensitivity	±0.25		%	Inherent sensor error, excluding misalignment
Nonlinearity	0.1	0.5	% FSR	Best fit straight line
Frequency Response, 5-pole	0	800	Hz	Upper cutoff per Option Bnnn, -3dB pt ±10%, 5-pole Butterworth filter
Noise Density	100		µg/√Hz	10 Hz to 400 Hz
Self-Test Pull-up Resistor	5		kΩ	Logic "1"≥3.5 V, Logic "0"≤1.5 V, "0" causes self-test
Temperature Sensor Sensitivity 0°C Bias Level	 6.45 509		 mV/°C mV	Accuracy ±1°C
Outputs Output Voltage Swing Capacitive Drive Capability	0.05 1000	4.95	V pF	I_{out} = ±0.5 mA
Power Supply (V_S) Input Voltage Limits Input Voltage - Operating Input Current Rejection Ratio	 -80 +8.5 12 >120	 +80 +36	 V V mA dB	 -80 V continuous, >38 V if ≤550 ms, duty <1% Continuous DC
Temperature Range (T_a)	-40	+85	°C	
Mass	38		grams	Precise values on Cal certificate
Shock Survival	-5000	+5000	g	Any axis for 0.5 ms, powered or unpowered

DataSheet Rev. 1.05

1.3 Command Syntax Analysis

The commands supported in the XL403D were developed based on the Standard Commands for Programmable Instruments (SCPI) Standard Version 1995.0. The XL403D does not conform to the standard, so the commands are only SCPI-like.

The commands are always ASCII-encoded and are acted upon when a <CR> character is sent, which is always at the end of each command. The XL403D will always respond with a <CR> when the command has been received.

The interface to the XL403D is half-duplex only; and, therefore, commands and data are never sent and received simultaneously. The interface is either sending or receiving at any moment in time.

Commands that end in a question mark (?) are query commands, which will always return information to the serial port. Query commands are often used to request the status of the sensor or to retrieve readings. All data sent in response to a query command are ASCII-encoded.

2.0 Concepts, Functions and Commands

2.1 Measurement Concepts

2.1.1 A *channel* is a data source from a sensor.

The XL403D has four pre-defined channels: A1, A2, A3 and T1. The "A" channels represent the three axes of acceleration that are sourced from the built-in accelerometer chip. The "T1" channel is the temperature channel, sourced from the built-in temperature sensor.

2.1.2 A *scan* is a set of readings from a defined set of channels.

A scan must be defined and then triggered to occur at a particular interval and from a particular source. A scan defines both the channels being scanned and the order in which they are scanned.

2.1.3 A *trigger* is an event that initiates a scan.

Once the XL403D is triggered, a measurement is taken from each channel in the scan. Triggers can come from four sources: AUTo, TIMe, EXT and BUS.

AUTo triggers are available immediately at all times, allowing the XL403D to take measurements as fast as possible.

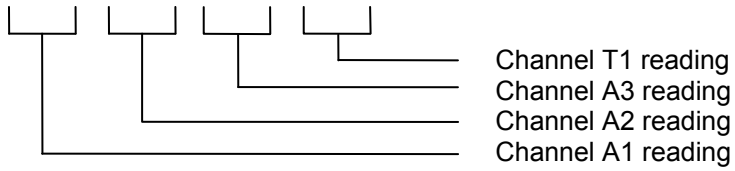
TIMe triggers are generated periodically at specified time intervals.

EXT triggers are generated by high-to-low TTL-level transitions on the XL403D's ST/AUX line.

BUS triggers are generated through the receipt of a command (i.e. "READ?").

The XL403D comes configured with all four input channels defined in the following order: A1, A2, A3 and T1. A typical default scan record will look like this:

```
READ?
0.57g,1.01g,0.79g,24.7°C
```



A scan record (with updated readings) will be sent each time a scan is generated. This cab be accomplished with a READ? command, but may be done using a timer or with a signal through the ST/AUX line.

All measurements to channels A1, A2 and A3 are taken using an A/D converter that is always clocked to produce a reading in 69 µsec. The T1 measure-ments are read directly from the on-board temperature sensor and require 2.5 µsec to complete. When processing overhead is included, the XL403D can scan 4 channels over 2500 times each second.

2.1.4 A *readings buffer* is temporary storage within the XL403D for measurements.

The current buffer size is 192 readings in size. All measurements are written to the buffer and processed from there. Readings are formatted for output or processed by functions while they are in the readings buffer. When more than 192 readings are measured by the XL403D, the new readings overwrite the oldest readings in the buffer by "wrapping around" to the beginning of the buffer. The buffer always contains the latest readings.

2.2 Scan and Measurement Speed Concepts

The XL403D may be used to simply take measurements and transmit them out the serial port. The sensor can take measurements and display them at various speeds, based on the triggering configuration and other settings in the XL403D. The configured BAUD rate and formatting options determine the maximum scan rate for the sensor.

The following table shows the maximum 4-channel scan throughput at various BAUD rates using the three triggering methods. The "Command" values include time for sending a "READ?" command and for transmitting a single scan. The "Timer/Ext" values include only time to format and transmit a scan. All values include time for processing overhead.

Trigger	*28800 BAUD*	*38400 BAUD*	*57600 BAUD*	*115200 BAUD*
Command	80	120	180	240
Timer/Ext	100	130	200	300

Table 2
Maximum 4-Channel Floating-Point

Scan Rates for the XL403D

The maximum scan rates increase as the number of scanned channels decreases.

The absolute maximum scan rate is approximately 1100 scans/second when scanning a single channel at 115200 BAUD.

The sensor may be placed in HEX format mode to increase its measurement throughput. This will transmit each channel's data as an unsigned HEX word, which requires only 2 bytes per channel. The scan record will be of a fixed length and will be terminated with a <CR>. This means that a HEX scan will have the following format:

```
C1,C2,C3,C4<CR>
            Where:      C1 = 2 bytes for channel 1's value
                        C2 = 2 bytes for channel 2's value
                        C3 = 2 bytes for channel 3's value
                        C4 = 2 bytes for channel 4's value
```

This changes the 4-channel scanning speeds to the following:

Trigger	*28800 BAUD*	*38400 BAUD*	*57600 BAUD*	*115200 BAUD*
Command	185	250	380	750
Timer/ST/AUX	230	300	450	950

Table 3
Maximum 4-Channel HEX
Scan Rates for the XL403D

Scanning is accomplished by defining a list of channels to scan, then initiating the scan. The following example shows how a scan is defined and initiated through the command interface.

Example:		
	`ROUT:SCAN:CAT?`	Obtain available channel list
	`A1,A2,A3,T1`	Channel list displayed
	`ROUT:SCAN A1,T1`	Set A1 and T1 in scan list
	`<CR>`	ACK sent by unit
	`READ?`	Initiate a scan
	`1.06g,21.3°C`	Scan data returned

By default, the unit scans as fast as possible. If required, the scans can be performed at a rate determined by a signal on the SelfTest/AUX input pin or by a timer in the unit (see Measurement Concepts, section 2.1.3)

2.3 Triggering Concepts

The XL403D will allow scans to be triggered from several sources: `AUTo, BUS, EXT` and `TIM.`

The default source ("AUTo") generates a trigger whenever the sensor needs one. This makes scanning happen as fast as possible.

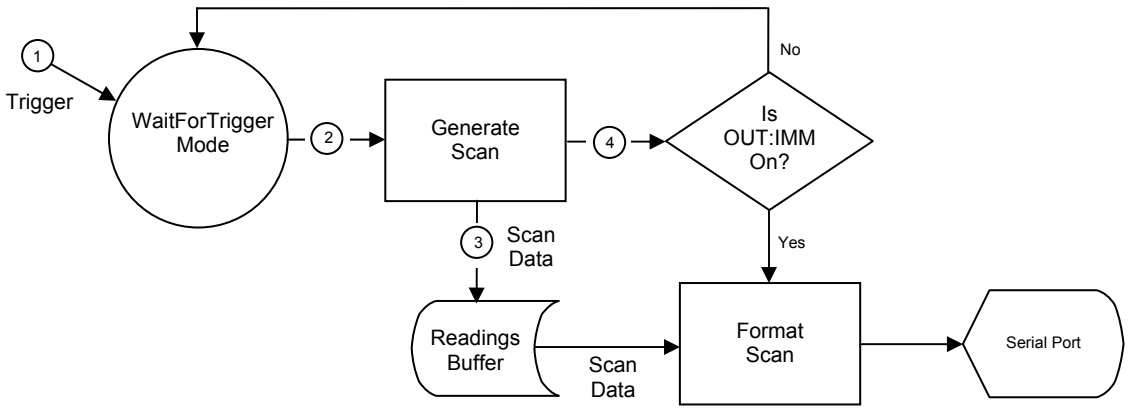
The sensor will initiate a scan immediately upon receiving a READ? command, also known as "BUS" triggering. This source is always available and will be automatically used when the READ? command is received.

Scans may also be initiated through a logic transition on the SelfTest/AUX line ("EXT" source). No SelfTest signals can be responded to in this mode, since there is no way to distinguish between asserting SelfTest and triggering on the line.

Finally, scans may be initiated based on a timer ("TIM" source). The internal timer can trigger scans from 0.0004 seconds to 1388 seconds apart.

The sensor is, by default, in Idle mode and does not respond to trigger events. To make the unit respond to trigger events, the unit must be placed into WaitForTrigger mode. In this mode, the next trigger event that is sensed will start a scan. To place the sensor in WaitForTrigger mode, issue the INIT command.

The unit listens for incoming characters after sending each scan record in order that the user may stop scanning and return the unit to Idle mode. Typically, a <CR> will suffice, although at higher scan rates a <BREAK> condition will be required to stop scanning. When the sensor is set to OUT:IMM OFF, the ABORT command must be entered in order to return to Idle mode.



The unit will always perform a single scan in response to a trigger event.

Periodic scans produce a continuous series of scan records until power is cycled, the unit is reset or the current scanning mode is canceled. The unit can also be configured to exit WaitForTrigger mode after a configurable number of triggers have occurred (from 0 to 65535). ***A value of 0 indicates "continuous" mode, where the unit will trigger scans continuously until WaitForTrigger mode is exited or the unit is reset.***

The result of triggering a scan is to (1) read each configured channel's sensor, (2) store the readings into the readings buffer/internal memory. The sensor's configuration determines what happens after that. If `OUT:IMM` is `ON`, then the sensor will format the scan's readings according to the current `OUT:FMT` settings and transmit the readings out the serial port. If there are any enabled functions, they will be evaluated according to their respective configurations.

2.4 Channel Data Conversion Concepts

The XL403D takes digital measurements at each trigger and stores the readings in the readings buffer. For efficiency's sake, the readings are not converted into external (formatted) representations until requested by the user, which occurs when the scan's readings are formatted for display. In `OUT:IMM ON` mode, the sensor will format scans for display immediately after they are stored in the reading buffer. In `OUT:IMM OFF` mode, readings are formatted and displayed only when the `R?` command is executed.

If the sensor is in Floating Point format, the readings are converted to engineering units using the calibration gain and offset values for each channel. If the sensor is placed in HEX format mode, no units conversion is performed: the readings are converted to HEX format and displayed. This allows the readings to be converted to engineering units using an external program, and increases the number of readings per second that can be read from the sensor.

2.5 Serial I/O Concepts

The XL403D has an on-board RS485 adapter, providing a fast and robust computer interface. Pins 5 and 6 on the DB9 connector are the RS485- and RS485+ pins respectively, which allow communications to and from the sensor. When powered-on, the interface is set to the following communication settings:

Baud rate	38400
Data bits	8
Stop bits	1
Parity	None

The sensor's BAUD setting can be changed using the `SYST:COMM:SER:BAUD` command. If necessary, that command can be placed in a startup script to make the change permanent.

2.6 AUX/ST Functionality

The AUX/SelfTest pin has the ability to perform several functions, based on the sensor's configuration. By default, the AUX pin is set as an input and is configured to respond to a high-to-low TTL-level transition (usually by grounding the pin) by asserting SelfTest on the sensor chips. In addition, the AUX pin can be configured to perform a scan when the pin's logic level transitions from high-to-low. The AUX pin can also be configured as an output signal, where it is TTL-logic high when all signals are within threshold and moves to TTL-logic low when a threshold is exceeded.

2.7 Command Set Overview

The following section describes each command available in the XL403D according to functional groups. All commands are acted upon when a <CR> is sent at the end of the command. All available commands are highlighted in a grey text box throughout this section.

2.7.1 Supported IEEE-488.2 Common Commands

*RST	Resets the sensor to power-on.
*IDN?	Displays the sensor's identification information.
*TST?	Displays the Power On Self Test results.

```
*RST
```

Resets the unit so that it runs the same code that it does at power-up. This will reset the sensor back to its power-up state. If there is a startup script defined, it will be executed.

```
*IDN?
```

Retrieves, formats and transmits the unit's identification information to the serial port. The output record is divided into the following comma-separated fields:

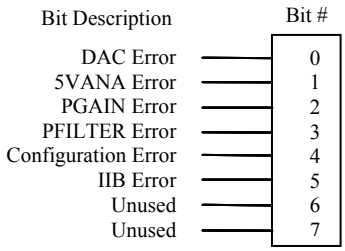
1 – Manufacturer
2 – Model number
3 – Serial number
4 – Firmware name
5 – Firmware version
6 – Firmware compilation date/time
7 – BootLoader version

2.7.1 Supported IEEE-488.2 Common Commands (con't)

Example:
```
*IDN?
Measurement Specialties,XL403D,2090A98765,RT,2.0054,May 24,2012 15:29:25,2.16
```

```
*TST?
```

Retrieves, formats and transmits the results of the unit's Power On Self-Test. The value is formatted as a HEX value. The results range from 0 to 255 with the following interpretation:



Example:
```
*TST?
0x0001
```

2.7.2 Calibration Commands

CAL:DATA?	Displays the current calibration values for each channel.
CAL:DATE?	Displays the last date/time of calibration.

```
CAL:DATA?
```

Returns the calibration data for each channel defined in the sensor. These values are used to convert the digital measurement into engineering units using the following formula:

```
EU = (Measurement – Offset) / Gain
```

Example:
```
CAL:DATA?
A1: gain=68.267, offset=512
A2: gain=68.267, offset=512
A3: gain=68.267, offset=512
T1: gain=4.0, offset=512
```

```
CAL:DATE?
```

Returns the most recent calibration date and time of the instrument.

Example:
```
CAL:DATE?
05-Nov-12 17:11
```

2.7.3 Configuration Commands

CONF:FNC:CAT?	Displays a list of all available functions.
CONF:FNC	Configures a function for execution.
CONF:FNC?	Displays data for all currently-enabled functions.
OUT:FMT	Configures scan formatting flags.
OUT:FMT?	Displays the current scan formatting flags.
OUT:IMM	Configures whether or not scans are immediately formatted for output.
ROUT:AUX	Configures the SelfTest/AUX pin's operational mode.
ROUT:AUX?	Displays the current operational mode for the SelfTest/AUX pin.
ROUT:SCAN:CAT?	Displays a list of all available input channels
ROUT:SCAN	Configures which channels are in scan.
ROUT:SCAN?	Displays a list of channels currently in scan.

```
CONF:FNC:CAT?
```

Lists the available data analysis functions to the serial port. The functions are displayed as a comma-separated list.

Example: `CONF:FNC:CAT?`
`MIN,MAX,MAG,PTP,---,TLT,TH1,TH2,OU1,OU2,OU3`

Name	*Description*
MIN	Maintains the minimum measurement on each channel.
MAX	Maintains the maximum measurement on each channel.
MAG	Calculates the magnitude of the result vector using A1, A2 and A3.
PTP	Calculates the Peak To Peak value for each channel (i.e. MAX-MIN)..
TLT	Calculates the tilt angle using any two axes using the atan2 trig. function.
TH1	Checks channel measurements against thresholds.
TH2	Checks the value of the MAG or TLT functions against thresholds.
OU1	Formats and prints the value of one or more functions to the serial port.
OU2	Formats and prints the value of one or more functions to the serial port.
OU3	Formats and prints the value of one or more functions to the serial port.

```
CONF:FNC <func_name> <config_val>,<interval> [<addt'l params>]
```

Configures an analysis function. The parameters specify the analysis function by name, its configuration value, and the number of scans that must be in the readings buffer before the function is evaluated.

If a function is DISABLED, it is *never* evaluated.

Some functions require additional parameters in order for them to execute. Each function will be explained based on its parameter requirements.

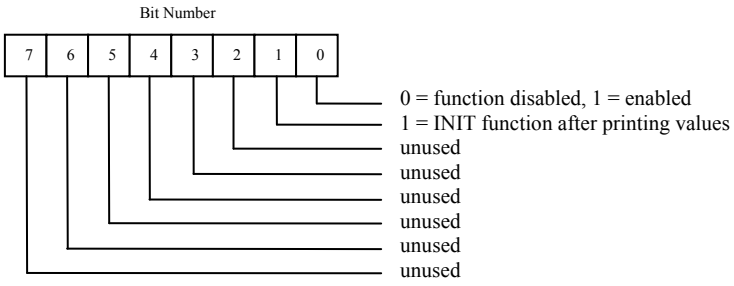
2.7.3 Configuration Commands (con't)

`MIN` – updates the minimum value for each channel.
`MAX` – updates the maximum value for each channel.
`PTP` – calculates Peak to Peak (`MAX` – `MIN`) values for each channel.

The `MIN, MAX` and `PTP` functions run very efficiently, since they operate on the readings in the buffer directly as integer values. No floating-point calculations need to be performed. These functions require only the following parameters:

```
<config_val>,<scan_interval>
```

The `<config_val>` is used to define the configuration value for the function. The value will be the logical OR of the following bits:



**** If a function is DISABLED, it is *never* evaluated.****

The `<scan_interval>` value defines how many unprocessed readings must be in the readings buffer before the function is evaluated against them. This allows a function to be evaluated every time a reading is taken (when set to 1) or to hold off evaluating the function until a larger group is in the buffer (when set to > 1). Therefore, a value of 10 would configure the function to be evaluated every tenth scan.

The `MIN`, `MAX` and `PTP` functions will check every reading in the buffer, even when they are evaluated at an interval greater than one. This allows the functions to catch up every time they are run. This capability can be used to minimize the overhead of calling the function every time a scan is generated while still being assured that the `MIN`, `MAX` and `PTP` values are representative of every scan that was performed.

Examples:

`CONF:FNC MIN 1,1`	Evaluates `MIN` every scan.
`CONF:FNC MAX 1,10`	Evaluates `MAX` every 10th scan.
`CONF:FNC MIN 3,250`	Evaluates `MIN` every 250th scan and initializes the function when its value is printed.

2.7.3 Configuration Commands (con't)

`MAG` – calculates the magnitude of the result vector using A1, A2 and A3.

All three axes (A1, A2 and A3) must be scanned for this function to work properly. This function requires only the `<config_val>,<scan_interval>` parameters. This function will calculate the magnitude against the latest scan in the buffer when evaluated.

Example:	`CONF:FNC MAG 1,1`	Calculates the magnitude every scan.
	`CONF:FNC MAG 1,10`	Calculates the magnitude every tenth scan.
	`CONF:FNC MAG 1,25`	Calculates the magnitude every 25th scan.

`TLT` – calculates tilt angle between any two axes.

This function calculates the tilt angle in a plane defined by any two axes. The two axes are defined as `<addt'l_params>` in the command. Their respective (normalized) readings are used as inputs into the `atan2` function, which returns the principal value of the arctangent of *y*/*x* using the signs of both arguments to determine the quadrant that the angle lies in. The angle is between -180 and +180 degrees. The first axis listed is *x* and the second is *y* when calculating the arctangent.

Examples:	`CONF:FNC TLT 1,10 A1,A2`	Evaluates tilt every tenth scan using the A1 axis as *x* and A2 as *y*.
	`CONF:FNC TLT 1,1 A2,A3`	Evaluates tilt every scan using the A2 axis as *x* and A3 as *y*.
	`CONF:FNC TLT 1,100 A1,A3`	Evaluates tilt every 100th scan using the A1 axis as *x* and A3 as *y*.

The `<config_val>` is used to define the configuration value for the function and its value has the same definition as explained previously for the `MIN`, `MAX` and `PTP` functions.

`TH1` – checks channel readings against thresholds.

This function checks channel readings against thresholds. The thresholds are entered separately for each channel, so each channel can have unique thresholds. Once the `CONF:FNC` command and the required parameters have been entered, followed by a `<CR>`, the sensor will display a prompt for each channel currently defined in scan. The threshold limit and reset values are entered, separated by commas, on each line, followed by a `<CR>`.

If threshold values are not to be applied to a channel, simply press `<CR>` at the prompt and that channel's threshold evaluation will be skipped. The command sequence resembles this:

2.7.3 Configuration Commands (con't)

Example:

```
CONF:FNC TH1 1,1
> A1:0.5,0.25
> A2:0.5,0.25
> A3:
> T1:
TRIG:SOUR TIM 0.25
INIT
0.352g, 0.088g,-0.762g, 31.5°C
0.381g, 0.088g,-0.747g, 31.3°C
0.396g, 0.088g,-0.747g, 31.3°C
0.425g, 0.088g,-0.747g, 31.5°C
0.454g, 0.088g,-0.732g, 31.5°C
0.469g, 0.073g,-0.718g, 31.8°C
TH1:A1 Over Limit
0.513g, 0.073g,-0.688g, 31.8°C
0.498g, 0.073g,-0.688g, 31.8°C
0.483g, 0.073g,-0.703g, 31.8°C
0.439g, 0.073g,-0.732g, 31.5°C
0.396g, 0.088g,-0.747g, 31.5°C
0.366g, 0.073g,-0.762g, 31.5°C
0.308g, 0.088g,-0.776g, 31.5°C
0.249g, 0.088g,-0.791g, 31.5°C
TH1:A1 In Limit
```

As this example shows, a message is sent to the serial port when a channel exceeds a threshold. If the AUX pin is configured to output threshold events (see the `ROUT:AUX` command), then it will transition from logic high-to-low for as long as the threshold condition exists.

`TH2` – checks magnitude and tilt function values against thresholds.

This function checks `MAG` and `TLT` function values against thresholds. The thresholds are entered separately for each function, so each can be unique. Once the `CONF:FNC` command has been entered, along with all required parameters, the sensor will display a prompt (a ">" character) and wait for the user to enter further data.

The function name, threshold limit and reset value are entered, separated by commas, on each line, followed by a `<CR>`. The command sequence resembles this:

2.7.3 Configuration Commands (con't)

Example:

`CONF:FNC TH2 1,1 > MAG,1.0,0.9`	Configure function value thresholds.
`CONF:FNC MAG 1,1`	Evaluate the MAG function every scan.
`TRIG:SOUR TIM 0.1`	Generate scans 10 times/second.
`OUT:IMM OFF`	Don't display the individual scan data.
`INIT`	Begin scanning.
`MAG:  0.80g`	
`MAG:  0.80g`	
`MAG:  0.80g`	
`MAG:  0.80g`	
`TH2:MAG Over Limit`	
`MAG:  2.32g`	
`TH2:MAG In Limit`	
`MAG:  0.71g`	
`MAG:  0.81g`	
`MAG:  0.81g`	
`Abort`	Stop scanning.

As this example shows, a message is sent to the serial port when a function value exceeds its threshold. If the AUX pin is configured to output threshold events (see the `ROUT:AUX` command), then it will transition from logic high-to-low for as long as the threshold condition exists. Only one function at a time (either `MAG` or `TLT`) can have its value checked against thresholds.

- `OU1` – outputs indicated results to serial port.
- `OU2` – outputs indicated results to serial port.
- `OU3` – outputs indicated results to serial port.

These functions are available for producing output from functions on a periodic basis. The effect of running one of these functions is the same as executing the `CONF:FNC <func_name> PRINT` command.

These functions require the `<config_val>`, `<scan_interval>` and `<addt'l_params>` parameters when they are configured. Typically, the `<interval>` is set to the same value as the function whose value is being printed. The `<addt'l_params>` is a comma-separated list of functions whose values are to be printed when the `OU*` function executes.

2.7.3 Configuration Commands (con't)

Examples:

```
TRIG:SOUR TIM 0.25          Generate scans 4 time/second.
OUT:IMM OFF                 Do not display the individual scan data.
CONF:FNC MAG 1,10           Evaluate the magnitude function every tenth scan.
CONF:FNC OU1 1,10 MAG       Print out the magnitude results every tenth scan.
INIT                        Begin scanning.
MAG:  0.80g
MAG:  0.80g
MAG:  0.82g
MAG:  0.82g
MAG:  0.72g
MAG:  0.68g
MAG:  0.69g
MAG:  0.80g
MAG:  0.80g
MAG:  0.80g
Abort                       Stop scanning.
```

2.7.3.1 Additional Configuration Parameters

`INIT`

This parameter instructs the sensor to initialize the indicated function. This sets its values back to power-on levels. For example, initializing the `MIN` or `MAX` function will cause new minimum and maximum values to be determined from the data.

`PRINT`

This parameter instructs the sensor to print out the current value(s) of the indicated function.

Examples:

```
CONF:FNC MIN 1,1
CONF:FNC MAX 3,1
CONF:FNC OU1 1,10 MIN,MAX
CONF:FNC MIN INIT
CONF:FNC MAX PRINT
-0.469g, 0.190g, 0.527g, 32.8°C
```

`CONF:FNC?`

Formats and displays the current configuration data for each ENABLED analysis function. The configuration data is as follows:

```
Config. Word
Scan interval
Scan counter
Scan buffer pointer
```

Example:
```
CONF:FNC?
MIN,0x0001,0x0001,0x0000,0x03E0
MAX,0x0001,0x0001,0x0000,0x03E0
OU1,0x0001,0x000A,0x0008,0x03E0
```

`OUT:FMT <format_flags>`

Configures the sensor to format scans according to the list of comma-separated flags.

Scans are formatted when they are placed in the readings buffer (when `OUT:IMM` is `ON`) or when the `R?` command is executed. The following flags are supported:

`FLT` – sets floating-point (engineering units) format mode
`HEX` – sets HEX-format mode

> **Note**
> The `<format_flags>` parameter *must* begin with either the `FLT` or `HEX` flag, followed by all other flags.

`UNI` – appends channel units to each reading
`CRC` – appends a HEX-formatted CRC value to the end of each scan record
`CNT` – prepends a HEX-formatted scan count value to each scan record
`BST` – appends HEX-formatted number of readings in buffer to each scan record
`TST` – appends HEX-formatted trigger information to each scan record (i.e. number of triggers defined and number of triggers processed)

Example:
```
OUT:FMT FLT,UNI,CNT
READ?
0001,-0.483g, 0.161g, 0.513g, 32.5°C

OUT:FMT HEX,CNT,CRC
READ?
000C,01DF,020A,0223,0280,E5E6
```

`OUT:FMT?`

Displays the set of formatting flags that are currently in effect. All flags are separated by commas.

Example:
```
OUT:FMT?
FLT,Units                    Floating-point and units enabled.
OUT:FMT HEX,CNT,CRC
OUT:FMT?
HEX,CRC,CNT                  Hex, CRC and scan count enabled.
```

```
OUT:IMM ON|OFF
```

Configures the sensor to format and display channel readings immediately after they are written to the readings buffer. This is set to "ON" by default. When set to "OFF", readings will be buffered, but not displayed. Readings in the buffer can always be displayed using the R? command.

```
ROUT:AUX <mode>,<flags>
```

Configures the sensor's AUX pin functionality. The following modes and flags are supported. No other combinations of modes and flags are supported by the XL403D.

Mode	*Flag*	*Description*
INP	TRG	Responds to high-to-low TTL-level logic transitions on the AUX pin. When the sensor is in Idle mode, a logic transition will place the sensor in SelfTest. When the sensor is configured for TRIG:MODE EXT and is in WaitForTrigger mode, logic transitions cause the sensor to generate a scan.
OUT	TRG	Causes the AUX pin to transition from high-to-low when a trigger is encountered in the sensor. This only occurs when the sensor is configured for TRIG:SOUR TIM <interval>. This setting is used for synchronizing data collection between multiple sensors. The other sensors must be configured for ROUT:AUX INP,TRG and TRIG:SOUR EXT for the synchronization to work.
OUT	EVT	Causes the AUX pin to transition from high-to-low when a threshold event occurs, and to return high when the event is past.

Example:
```
ROUT:AUX OUT,TRG
TRIG:SOUR TIM 0.01
INIT
```

```
ROUT:AUX?
```

Displays the current AUX pin configuration, both mode and flags.

Example:
```
ROUT:AUX?
INP,TRG
ROUT:AUX OUT,EVT
ROUT:AUX?
OUT,EVT
```

```
ROUT:SCAN:CAT?
```

Displays the catalog of available channels for scanning.

2.7.3 Configuration Commands (con't)

Example:
```
ROUT:SCAN:CAT?
A1,A2,A3,T1
```

```
ROUT:SCAN <chan_list>
```

Defines the list of channels measured for each scan. The `<chan_list>` parameter is a comma-separated list of channels to be measured when a scan is triggered.

Example:
```
ROUT:SCAN A1,A2,T1
READ?
-0.483g, 0.146g, 32.3°C
```

```
ROUT:SCAN?
```

Displays the current list of channels in scan.

Example:
```
ROUT:SCAN?
A1,A2,T1
```

2.7.4 Input Commands

`FETCH:TEMP?`	Displays the latest digital temperature reading in HEX.
`INP:FILT:FREQ`	Configures the low-pass filter cutoff frequency.
`INP:FILT:FREQ?`	Displays the low-pass filter's cutoff frequency.
`INP:MODE:ST`	Sets or clears SelfTest mode.
`READ?`	Initiates a scan and writes the readings into the readings buffer.
`R?`	Formats and displays all non-displayed readings in the readings buffer.

```
FETCH:TEMP?
```

Displays the last digital temperature reading. The value is displayed in HEX format.

Example:
```
FETCH:TEMP?
0x027E
```

```
INP:FILT:FREQ <freq>
```

Sets the low pass frequency of the 5-pole Butterworth filter. The units are hertz. The frequency value must be between 1 Hz and 1193 Hz. This command affects only the 5-pole Butterworth filter's setting. The sensor chip has a built-in 1200Hz low-pass filter that interacts with the 5-pole filter's setting, resulting in a combined low-pass filter setting that is somewhat different than the setting of this frequency. The following equation may be used to calculate the setting required for the 5-pole Butterworth filter in order to achieve a desired cutoff for the entire circuit:

2.7.4 Input Commands (con't)

$$f_{\text{butterworth}} = f_{3\text{dB}} \left[\frac{1 + (f_{3\text{dB}} / 1200)^2}{0.995 - (f_{3\text{dB}} / 1200)^2} \right]^{1/10}$$

where: $f_{butterworth}$ = frequency setting for the 5-pole Butterworth filter
f_{3dB} = desired -3dB cutoff filter frequency for the sensor

As an example, the Butterworth filter needs to be set to 518 Hz ($f_{butterworth}$) in order to achieve a sensor cutoff of 500Hz (f_{3dB}).

```
INP:FILT:FREQ?
```

Returns the low pass filter frequency in hertz. This represents the setting of the 5-pole Butterworth filter only. The low pass filter frequency of the sensor may be somewhat different, as discussed above.

Example:
```
INP:FILT:FREQ?
100 Hz
INP:FILT:FREQ 1500
INP:FILT:FREQ?
1500 Hz
```

```
INP:MODE:ST ON|OFF
```

Sets the sensor's SelfTest mode (by driving the Self Test chip signal on the sensor chips)

```
READ?
```

Initiates a scan of all currently-defined channels. This takes a measurement on each channel, in its defined order, and writes the measurements to the readings buffer.

```
R?
```

Formats and displays all scans in the readings buffer. The data is formatted according to the current configuration defined by the `OUT:FMT` command and according to the current number of channels in each scan (as defined by the `ROUT:SCAN` command).

Example:
```
ROUT:SCAN?
A1,A2,A3,T1
INIT
R?
-0.015g,-0.020g,-1.000g, 30.3°C
-0.000g,-0.035g,-1.015g, 30.0°C
```

2.7.5 Trigger Commands

`ABORT`	Exits WaitForTrigger mode (enters Idle mode).
`INIT`	Enters WaitForTrigger mode (exits Idle mode).
`TRIG:SOUR`	Configures the source for future triggers.
`TRIG:SOUR?`	Displays the current trigger source.
`TRIG:COUNT`	Sets the number of triggers that may be generated.

TRIG:COUNT?	Displays the number of triggers to be generated.

```
ABORT
```

Places the sensor in Idle mode when it is in WaitForTrigger mode. This command is *only* needed when OUT:IMM is set to OFF and the sensor is in WaitForTrigger mode.

When OUT:IMM is ON and the sensor is scanning, a <CR> character (or a <BREAK> condition) can be used to make the sensor exit WaitForTrigger mode and return to Idle.

```
INIT
```

Places the sensor in WaitForTrigger mode when it is in Idle mode. This is required to begin taking readings.

Example:
```
TRIG:COUNT 5
INIT
-0.483g, 0.161g, 0.513g, 32.5°C
-0.483g, 0.146g, 0.513g, 32.5°C
-0.483g, 0.146g, 0.513g, 32.5°C
-0.483g, 0.146g, 0.513g, 32.5°C
-0.483g, 0.146g, 0.513g, 32.3°C
```

```
TRIG:SOUR EXT
TRIG:SOUR TIM <interval>
```

Configures the sensor to generate scans when certain trigger conditions are met. When the EXT parameter is specified, the sensor will generate a scan whenever a high-to-low transition is seen on the AUX/ST pin. When the TIM parameter is specified, the sensor will generate a scan when the indicated time interval (in seconds) has elapsed.

Example:
```
TRIG:SOUR TIM 0.01
```
This configures the sensor to generate a scan 100 times per second.

```
TRIG:SOUR?
```

Displays the current TRIG:SOUR settings in the sensor. The current mode (TIM or EXT) is displayed, followed by the time interval (if necessary). If the sensor is in TIM mode, the number of scans per second is displayed as well.

2.7.5 Trigger Commands (con't)

Example:
```
TRIG:SOUR TIM 0.025
TRIG:SOUR?
TIM    0.0250 (40 scans/sec)
```

```
TRIG:COUNT <count>
```

Sets the number of triggers that the unit will act upon before re-entering Idle mode. This can be used to limit the number of scans generated.

Example:
```
TRIG:SOUR TIM 0.005
TRIG:COUNT 512
INIT
```
This configures the sensor to generate 512 scans at 5 msec intervals.

```
TRIG:COUNT?
```

Displays the number of scans the sensor is currently configured to perform.

Example:
```
TRIG:COUNT?
512
```

2.7.6 Status Commands

DATA:PTS?	Displays the number of readings in the readings buffer.
SENS:RANGE?	Displays the range of every axis.
DIAG:LOAD?	Displays the current processing load on the sensor.

```
DATA:PTS?
```

Formats and displays the number of scans currently in the readings buffer. Use the R? command to retrieve the readings in the buffer.

Example:
```
DATA:PTS?
115
```

```
SENS:RANGE?
```

Formats and displays the sensor's range for each axis.

Example:
```
SENS:RANGE?
±  7.5g,±  7.5g,±  7.5g
```

```
DIAG:LOAD?
```

2.7.6 Status Commands (con't)

Displays a value that represents the current load on the sensor. This is a representation of how busy the sensor will be when performing scanning and data analysis. This value must be less than 90% (0.9) or the `INIT` command will generate an error condition and the sensor will not go into WaitFor Trigger mode. Higher scan rates and configuring one or more data analysis functions will increase this value. Either lowering scan rates or configuring analysis functions to be evaluated at longer time intervals will lower this value.

Example:
```
TRIG:SOUR TIM 0.1
DIAG:LOAD?
0.007
TRIG:SOUR TIM 0.001
DIAG:LOAD?
0.264
```

2.7.7 System Commands

SYST:ECHO	Echoes characters to the serial port.
SYST:ERR?	Displays (and clears) the sensor's current error status.
SYST:COMM:SER:ABAUD?	Displays the sensor's serial port configuration word.
SYST:COMM:SER:BAUD	Configures the sensor's serial port BAUD rate.
SYST:MODE:PROMPT	Configures the sensor's prompt mode.
SYST:MODE:STATUS	Configures the sensor's status mode.
SYST:SCRIPT	Defines the sensor's startup script.
SYST:SCRIPT?	Displays the sensor's startup script.
SYST:UPTIME?	Display the sensor's approximate uptime, in seconds.
SYST:RESET?	Displays the reason for the sensor's last reset.

```
SYST:ECHO <line of text>
```

This command simply echoes the indicated line of text to the RS-485 port. This can be used to document current activity in the XL403D when executing a startup script. The XL403D's input command buffer is 32 characters in length; therefore, this command supports a line of text up to 21 characters long.

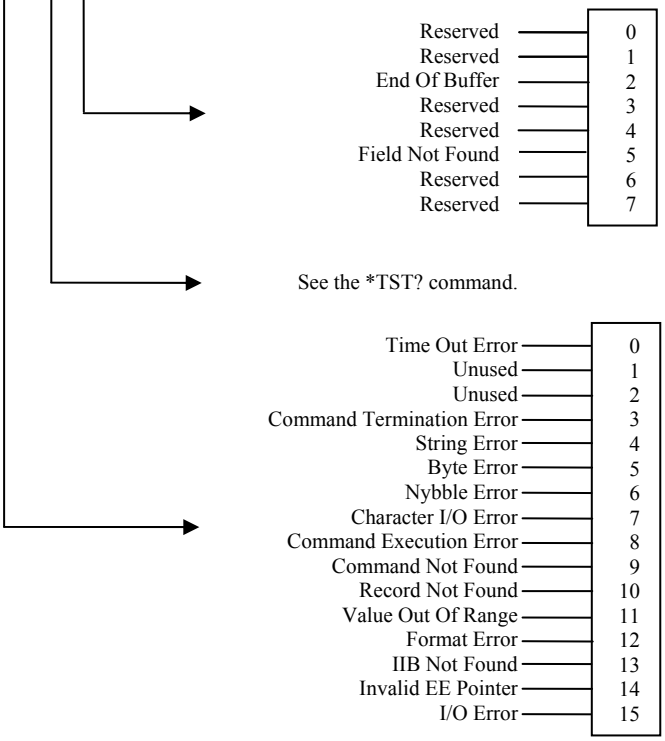
Example:
```
SYST:ECHO ===== Startup =====
===== Startup =====
TRIG:SOUR TIM 0.01
...
```

```
SYST:ERR?
```

This command displays any current error conditions that exist in the XL403D. These conditions are displayed as four HEX-formatted byte values, as shown below:

2.7.7 System Commands (con't)

Example: `SYST:ERR?`
`0x00000000`




```
SYST:COMM:SER:ABAUD?
```

Displays the current value of the Baud Rate Control Register in HEX.

Example: `SYST:COMM:SER:ABAUD?`
`0x000C`

```
SYST:COMM:SER:BAUD <baud:rate>
```

This command changes the configuration of the USART in the sensor to communicate at the indicated BAUD rate. Values for `<baud_rate>` can range from 2400 to 115200 and even higher, if a USB-to-RS485 interface is used.

```
SYST:MODE:PROMPT ON|OFF
```

Configures the sensor to display a prompt (a ">" character) after each command is executed (when set to ON).

```
SYST:MODE:STATUS ON|OFF
```

Configures the sensor to display status information if a command fails to execute due to an error condition.

Example:
```
SYST:MODE:STATUS ON
SUST:ERR?
SYNTAX?:1300FC02:SUST:ERR?
```

`SYST:SCRIPT`

This command places the sensor is "Script Definition Mode", indicated by the "`[SDM enabled]`" message that is displayed immediately after the command is executed.

All commands entered after this point are stored in the sensor's startup script. This script is executed at power-up or when the `*RST` command is executed.

To exit SDM mode, enter a `<CR>` on a line by itself.

Example:
```
SYST:SCRIPT
[SDM enabled]
SYST:ECHO ===== STARTUP =====
TRIG:SOUR TIM 0.01
TRIG:COUNT 128
CONF:FNC MIN 1,1
CONF:FNC MAX 1,1
CONF:FNC OU1 1,8 MIN,MAX
<CR>
[SDM disabled]
```

`SYST:SCRIPT?`

Displays the contents of the currently-defined startup script in the sensor. The number of bytes used is also displayed.

Example:
```
SYST:SCRIPT?
SYST:ECHO ===== STARTUP =====
TRIG:SOUR TIM 0.01
TRIG:COUNT 128
CONF:FNC MIN 1,1
CONF:FNC MAX 1,1
CONF:FNC OU1 1,8 MIN,MAX

123 of 256 bytes used
```

`SYST:UPTIME?`

2.7.7 System Commands (con't)

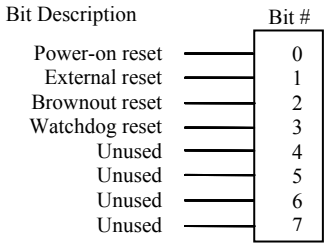
Displays the approximate number of seconds that the sensor has been powered-up. This value is reset to zero when power is lost and restored, when the sensor is reset or when the `*RST` command is executed.

Example:
```
SYST:UPTIME?
465 secs
```

`SYST:RESET?`

Displays the status value indicating the reason for the last reset condition. The HEX-formatted value is interpreted according to the following example.

Example:
```
SYST:RESET?
0x05
```



3.0 XL403D Default Settings

The following settings are in effect when the sensor is powered-up with no startup script defined.

- The sensor is in Idle mode and does not respond to trigger events (`INIT`).
- The sensor is in `AUTo` trigger mode (`TRIG:AUT`).
- The sensor will perform an infinite number of scans once triggering is initiated (`TRIG:COUNT 0`).
- The sensor scans with all four channels and will format the readings as comma-separated floating-point values with channel units displayed (`ROUT:SCAN A1,A1,A3,A4` and `OUT:FMT FLT,UNI`).
- The sensor will format each scan as it is generated and transmit it out the serial port (`OUT:IMM ON`).
- The serial port is set to 38400 BAUD, 1 stop bit, 8 data bits, no parity (`SYST:COMM:SER:BAUD 38400`).
- No functions are enabled (`CONF:FNC`).
- The AUX pin is set as an input and is configured to respond to a high-to-low TTL-level transition by placing the sensor in SelfTest mode(`ROUT:AUX INP,TRG`).

4.0 How to Use the XL403D

4.1 Sensor Power

The sensor requires power in order to operate. This power must be applied to DSUB pins 8 and 9 according to the specifications listed in section 1.2.1 (Data Sheet). The 35250AAK0/1 PC Interface Adapter provides a power supply that can be used for this purpose.

4.2 Sensor PC Connection

The XL403D requires an RS-485 PC interface kit to connect to a computer. The only software that is required on the computer is an ASCII terminal emulator. The HyperTerminal program that comes free with Windows does not work very well, since it always attempts to interpret the output of the XL403D in terms of a terminal emulation protocol, like ANSI. A better terminal emulator would be Tera Term Pro (or similar program) which can be configured for simple ASCII operation.

Plug the 35250A interface into the 9-pin DSUB connector on the XL403D first. This makes sure that the sensor is correctly connected to the interface. Next, plug the RS-232 cable into the other end of the 35250A and the serial port on the PC. A USB-to-RS232 interface may be necessary to attach the XL403D to your computer. Finally, plug the power supply into the 35205A's power port.

When the XL403D has been connected to the 35250A PC Interface, and that to the PC, and power has been supplied to the XL403D, it is ready for use.

4.3 Sensor Identification

The XL403D supports several status-type commands. These are shown in Figure 1 below and are used to query the identification of the device and its current status. Section 2.7 describes each command shown in Figure 1 and their responses.

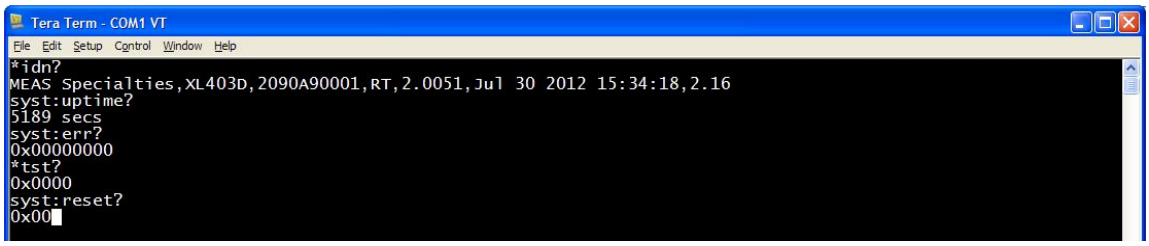


Figure 1
Identification Commands

4.4 Scan Configuration

Figure 2 shows the commands that can be used to configure the XL403D's scanning process. The `ROUT:SCAN?` command displays the current list of channels that are being scanned (in this case, all of them) and the `ROUT:SCAN` command is used to set the list of channels to be scanned. The `READ?` command initiates a single scan, which is immediately formatted and displayed upon completion.

The INP:FILT:FREQ? command displays the current cutoff filter's setting and the INP:FILT:FREQ command allows the user to set the cutoff frequency. Finally, the XL403D is configured for time-based scanning (at 100 scans/sec) for 25 scans (using the TRIG:SOUR:TIM and TRIG:COUNT commands, respectively). The INIT command begins the scanning process, which stops automatically after 25 scans have been performed.

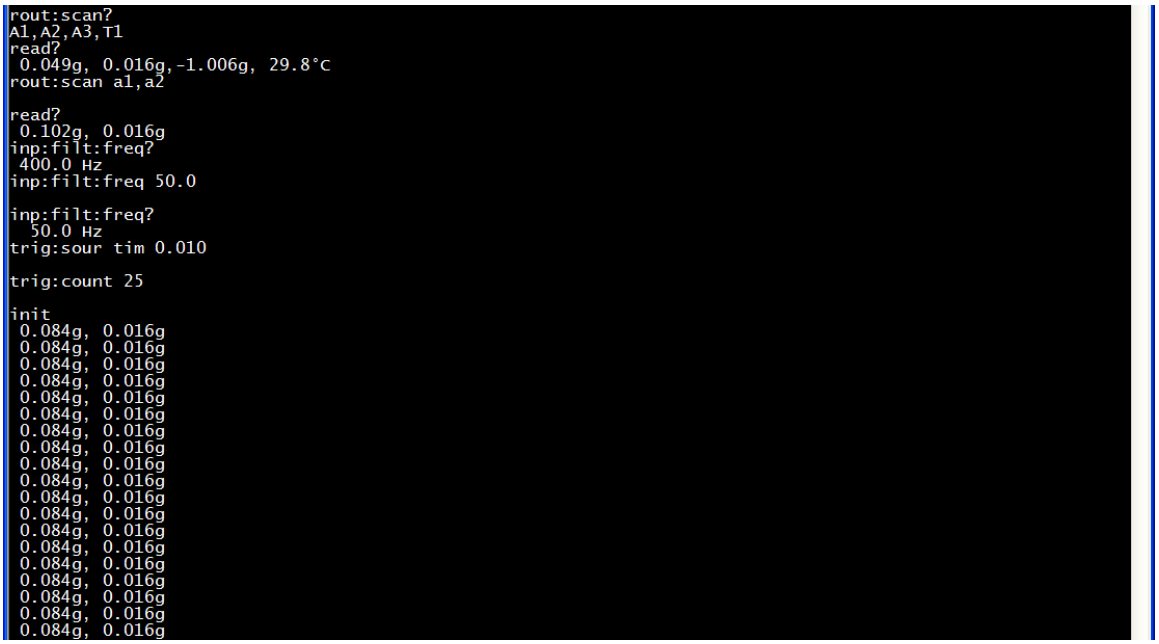


Figure 2
Scan Configuration Commands

By default, the number of scans is set to 0, which instructs the XL403D to generate scans forever, or until the user presses <CR> or issues a <BREAK> on the serial line.

4.5 Format Configuration

The results of each scan that the XL403D generates is formatted for output according to the settings of the OUT:FMT command. The OUT:FMT? command is used to display the current formatting flags that are in place. The supported flags are:

- FLT – converts readings into engineering units (floating-point).
- HEX – converts readings into HEX values for display.
- UNITS – appends each channel's units to its formatted display value.
- CNT – prepends a scan counter (in HEX) to the beginning of each scan.
- CRC – appends a CRC value (in HEX) to the end of each scan.

Figure 3 shows the default format setting, and shows how to change the format flags and the effect they have on the scan output.

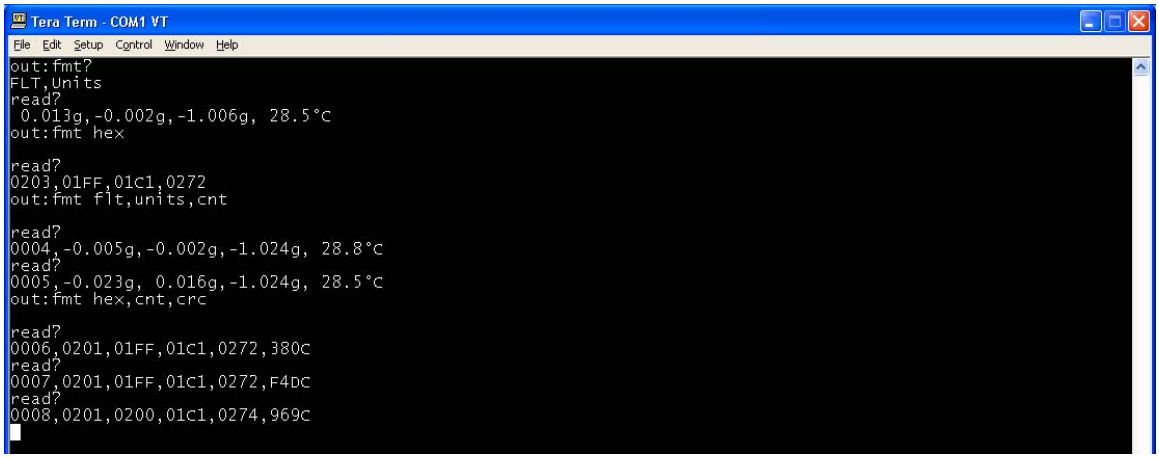


Figure 3
Output Format Configuration Commands

4.6 Function Configuration

The XL403D has built-in functions that can be configured to execute as often as desired. Each performs a unique function on the scan measurements and the result of each function is maintained internally. The value of each function can be displayed at any time using the `CONF:FNC <name> PRINT` command, or one of the three output functions can be configured to display the values on an ongoing basis. Figure 4 shows the commands used to display the function configuration, to change it and to display their output.

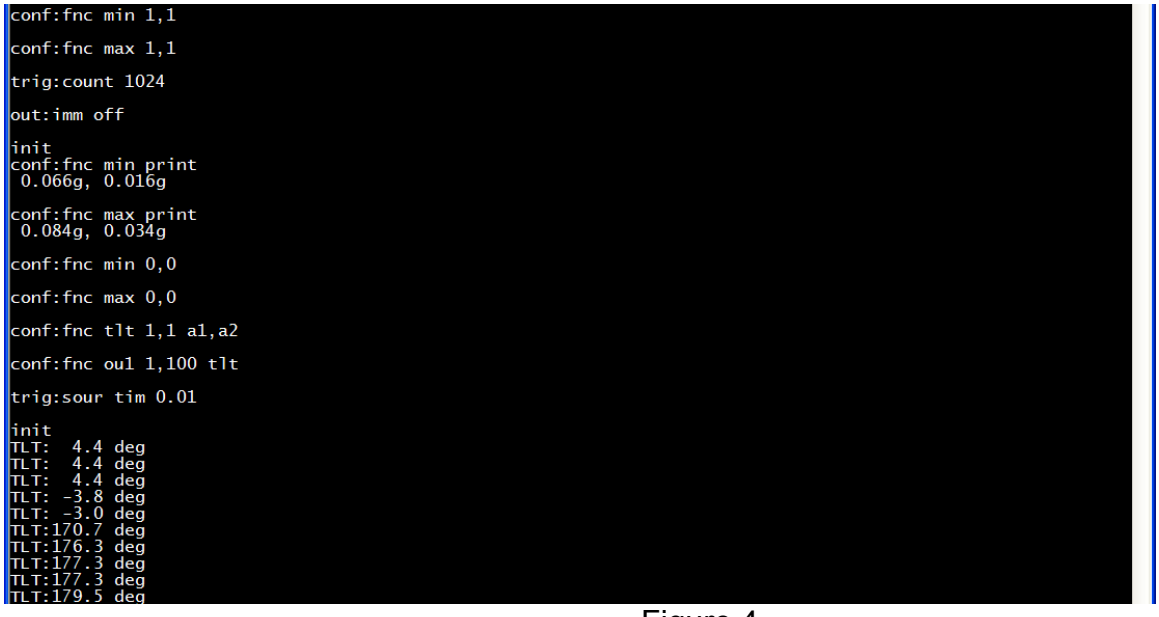


Figure 4
Function Configuration Commands and Results

The complete list of available functions is as follows:

1. MIN – tracks the minimum reading on each channel since the function was configured.
2. MAX – tracks the maximum reading on each channel since the function was configured.
3. MAG – calculates the magnitude of the vector sum of axes A1, A2 and A3.
4. PTP – tracks the peak-to-peak value for each channel since the function was configured. This is equal to (MAX – MIN) for each channel.
5. TLT – calculates the 2-axis tilt angle for any 2 axes that are in scan.
6. TH1 – tracks channels readings against individual channel threshold values.
7. TH2 – tracks MAG or TLT values against a threshold.
8. OU1/OU2/OU3 – output functions that print the values of functions on a configurable periodic basis.

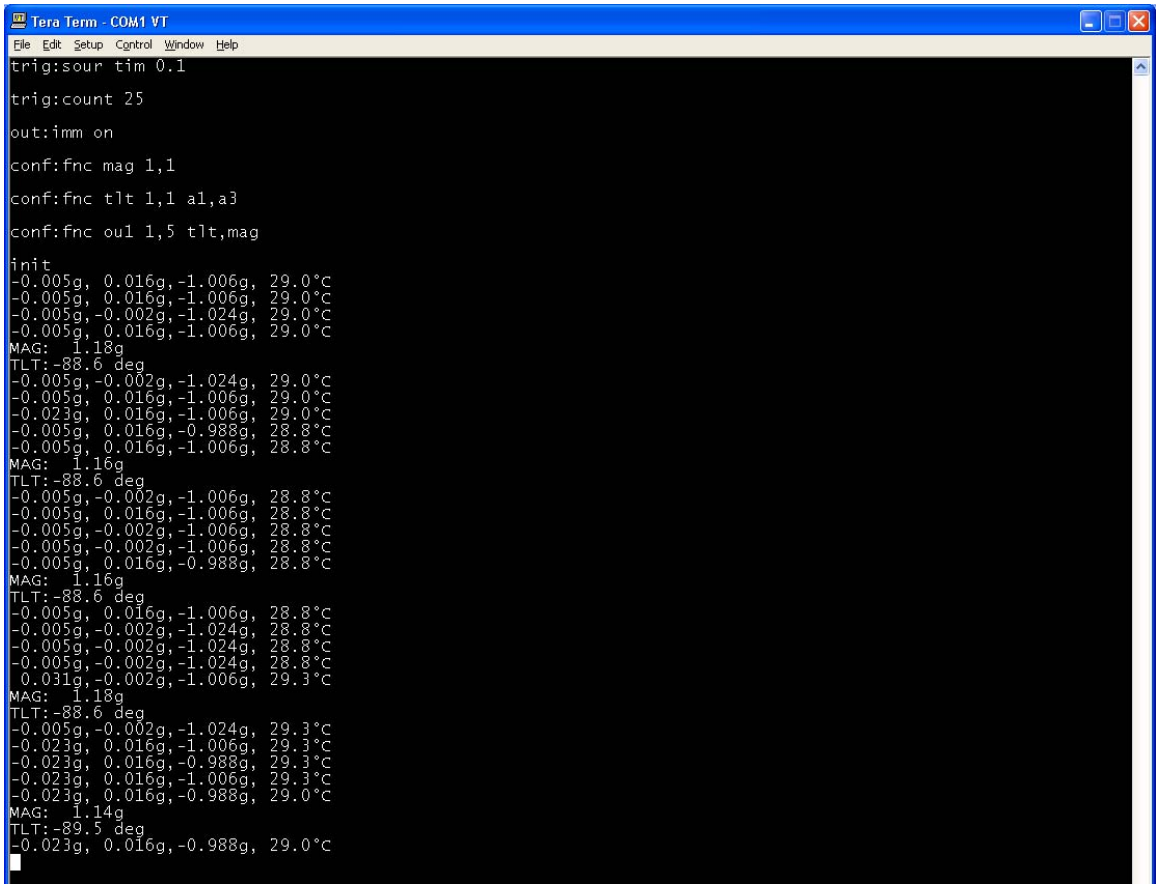


Figure 5
Function Output with Scan Measurements

Complete documentation for each command can be found in section 2.7.

5.0 Mounting Instructions

Use two 3.0 mm x 0.5 mm thread machine screws to attach to one of the three XL403D mounting faces [recommended torque 5 lbf-in (0.56 N.m)].

DO NOT thread a screw more than 2.5 mm (0.100 inch or 5 turns) into any XL403D mounting face as this can damage the sensor and will VOID the warranty.

A light film of oil or silicone grease can be used to enhance contact between two mounting surfaces.

A locking compound should be used on all threads to prevent screws loosening due to vibrations.

Accelerometer Connections

Pin	Description	Cable Wire	
1	Accelerometer 1	Brown	twisted pair
2	Accelerometer 2	Red	
3	Accelerometer 3	Orange	twisted pair
4	Signal	Yellow	
5	RS485-	Green	twisted pair
6	RS485+	Blue	
7	Self Test	Violet	twisted pair
8	$+V_S$ (Power)	Grey	
9	Ground*	White	

**connected to braided shield at D-shell pin*

Improper wiring can cause permanent damage and void the warranty.

Pins other than +Vs should not exceed 5 V

6.0 Product Warranty

6.1 Three-Year Limited Warranty Information

Measurement Specialties warrants this product against defects in materials and workmanship for a period of three years from date of shipment. During the warranty period, Measurement Specialties will, at its option, either repair or replace products which prove to be defective.
This warranty does not apply to defects or damage resulting from:

- Improper installation or maintenance
  - **Improper wiring can cause permanent damage and void the warranty.*
  - **Improper mounting can cause permanent damage and void the warranty.*
- Customer supplied software or interfacing
- Unauthorized modification or misuse
- Operation outside of the product specifications listed on the datasheet.

The warranty set forth above is exclusive and no other warranty, whether written or oral, is expressed or implied. Measurement Specialties specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

Some jurisdictions do not allow limitations on how long an implied warranty lasts, so the above limitation or exclusion may not apply to you. However, any implied warranty of merchantability or fitness is limited to the three-year duration of this written warranty.

6.1.1 Warranty Service

To obtain service during the warranty period, products must be returned, transportation prepaid, to Measurement Specialties. Call 1-330-659-3312 to obtain a return authorization. An RMA number will be issued prior to the return.